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FABRIC TOUGHNESS AS AN INDICATION TO CLOTHING DURABILITY FOR SELECTED BLEND PET AND CELLULOSIC FIBER FABRICS

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ABSTRACT

The performance of fabric is affected by chemical, physical and mechanical properties of its fibers and yarns. One mechanical property that is usually overseen is toughness which gives an important indication about the durability of the fabrics as it demonstrates the ability of the material to withstand sudden shocks of a given energy. Toughness can be regarded as a combined result of tensile strength and elongation. This study was concerned with the effect of material type and toughness results achieved by fabrics made out of these fibers. It was revealed that rayon has the most toughness, followed by cotton as it was found that fiber length played an important role in those results.

I. INTRODUCTION

The behavior of fabric is affected by chemical, physical and mechanical properties of its constituent fibers, fiber content, physical and mechanical characteristics of its constituent yarns, and the finishing treatments which are applied on it [1][2]. In this regard the mechanical properties are affected by the direction of the load and its tension. The mechanical properties of fabrics can be expressed in uniaxial or biaxial tensile properties, compression, shearing properties, bending rigidity, bursting and tear resistance [1].

II. MECHANICAL PROPERTIES OF WOVEN FABRICS

Numerous parameters influence the mechanical properties of woven fabrics. Firstly, there are fiber properties, and their molecular properties and structure. The mechanical properties of fibers depend on their molecular structure, where macromolecules can be arranged inline (unique arrangements of molecules) or amorphous (coincidental arrangements of molecules) structure[1][3]. The macromolecules are orientated mostly along the fiber axis and are connected to each other with intermolecular bonds. When a force is applied, the supramolecular structure starts changing[1][4]. Moreover, the fiber length and the type of spinning influence the yarn properties, while the fabric properties are also influenced by warp and weft density of the woven fabrics, and weave. In addition, the mechanical properties are also influenced by the weaving conditions, e.g. speed of weaving, warp insertion rate, weft beat-up force, the way of shed opening, warp preparation for weaving, warp and weft tension, and number of threads in reed dent, etc. Finally, the properties of raw fabrics consequently depend on the construction and technological parameters[1].

Tensile properties of fabrics

For designing apparel as well as for other uses, the knowledge about the tensile properties of woven fabrics is important. Strength and elongation are the most important performance properties of fabrics governing the fabric performance in use. Their study involves many difficulties due to a great degree of bulkiness in the fabric structure and strain variation during deformation. Each woven fabric consists of a large amount of constituent fibers and yarns, and hence, any slight deformation of the fabric will subsequently give rise to a chain of complex movements of the latter [5]. Consequently, at the beginning of loading, extension occurs in amorphous parts, where primary and secondary bonds are extending and are shear loaded. If in this stage, an external force stops acting, most of the achieved extension will recover and the material shows elastic properties. On the other hand, If the loading continuous, a plastic deformation of the material occurs. Long chains of molecules are reciprocally re-arranged as a consequence of the disconnection of secondary bonds. The re-arrangements of the reciprocal position of molecules give material better possibility to resist additional loading. If the loading continuous, a final break will occur [6][7]. Moreover, the tensile behavior of fabrics is closely related to the inter-fiber friction effect, the ease of crimp removal, and load-extension properties of the yarn themselves [1]. As a results, the tensile properties of fabrics mostly depend on the tensile properties of yarns [8]

Elongation at break

The elongation necessary to break a fiber or yarn or fabric is a useful quantity. It may be expressed by the actual, the fractional or the percentage increase in length, and is termed the breaking extension or break extension.[7]

Work of rupture

The work of rupture gives a measure of the ability of the material to withstand sudden shocks of a given energy. If the work of rupture is less than what is required to withstand this sudden shock the affected material will break. The capacity of a textile material to absorb energy is obviously useful in such applications as car seatbelts, or climbing ropes where the ability to safely

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slow down a moving body is important. It also has importance in other areas which are not so obvious such as tearing resistance, or abrasion resistance where high-energy absorption improves these properties [6]. The work of rupture is sometimes called toughness. The unit for work of rupture or toughness is joule. As a result, if we consider a fiber or yarn or fabric under a load (F), which causes an increase in length by an amount dl, then work done can be expressed by the following equation;
work done = force × displacement = F.dl [7]
This research is concerned with the toughness of blended fabrics of PET warp yarns and cellulosic weft yarns of flax, cotton, and rayon respectively in an effort to study the relation between fiber type and fabric toughness to estimate the ability of the fabrics to survive under abrupt shocks with a given energy [9].

III. MATERIALS AND METHOD

To evaluate the effect of the selected materials on toughness of fabrics, 3 samples were selected as listed in Table (1). For all samples, the warp thread count was 150 denier, and the weft count was equivalent to 30 Ne. The warp densities were set to 72 warps/cm, and fiber material was PET. On the other hand, weft densities were 36 picks/cm and weft materials were flax, cotton, and rayon respectively. All fabrics were woven by a plain 1/1 weave. All samples were tested for tensile strength according to ASTM 5035 [10].

IV. RESULTS AND DISCUSSION

Table (1) the specifications of produced samples

Specifications of fabrics					
Sample no.	**Warp fiber type**	**Weft fiber type**	**Warp density/cm**	**Pick density/cm**	**Weave type**
(1)	PET	Flax	72	36	Plain 1/1
(2)	PET	Cotton	72	36	Plain 1/1
(3)	PET	Rayon	72	36	Plain 1/1

Results of tensile strength and elongation are tabulated in Table (2)

Table (2) tensile strength and elongation of fabrics

Test direction	Test	PET/ Flax	PET/ Cotton	PET/ Rayon
Warp direction	Tensile strength (N)	1851	2118	1946
	Elongation (%)	60.7	62.8	64.9
Weft direction	Tensile strength (N)	612	460	580
	Elongation (%)	2	5.25	15

One way ANOVA test was conducted to measure the significance of results within the tested groups, and results are tabulated in annex (A) for tensile strength and elongation in both warp and weft directions.

The tensile strength and elongation in warp direction

After analyzing the ANOVA results for tensile strength and elongation in warp direction, as listed in Annex (A-1), all groups were found to be insignificant.

The tensile strength and elongation in weft direction

After analyzing the ANOVA results for tensile strength and elongation in weft direction, as listed in Annex (A-2), all groups were found to be significant where ($F=12.14 \geq Fcrit=5.14$) and ($F=1195.7 \geq Fcrit=5.14$)for both tensile and elongation results respectively.
Flax fibers show the highest tensile strength when compared to rayon, and cotton respectively. This is due to the highly crystalline nature of flax fiber polymer. In addition, the length of flax fiber proved to be the highest in comparison to rayon and cotton fibers. On the other hand, flax fiber showed the least elongation when compared to the other two fibers. As a consequence, flax fibers are

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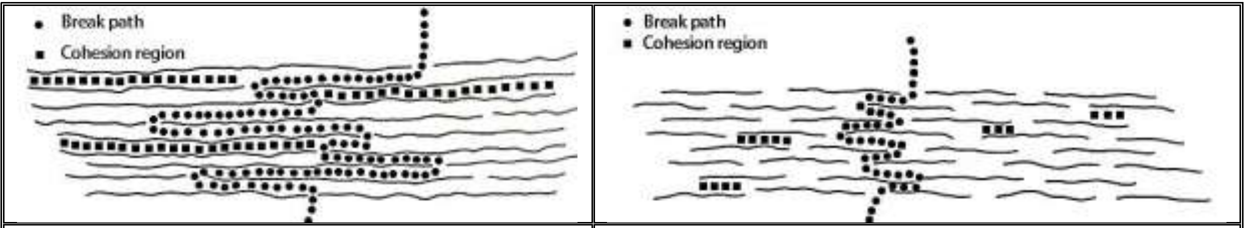
classified as brittle [11]. In other words, flax fibers can not deform very much before it breaks. A perplexing observation as shown in Table (2) is that rayon fibers have more strength than cotton fibers. This seems illogical at the first sight because it is on contrary with the scientific fact that states that there is a positive relation between crystalline region of fibers and the tensile strength of it [4]. But this fact can be applied when the fiber length of both fibers are the same which in our case is not. This odd observation can be explained by the fiber length of the rayon which was found to be around 80 mm while the length of cotton was around 36 mm.



Rayon fiber	Cotton fiber

Fig. (1) Fiber length of rayon and cotton

As illustrated in Figure (1) the cohesion points between rayon fibers are more than cotton. Therefore the blend of PET /rayon fabric recorded a higher tensile strength than PET/cotton although the crystalinity of rayon is less than cotton. On the other hand, the rayon fibers elongation results recorded higher elongation than cotton. Consequently, the toughness of PET/rayon fabric is more than PET/cotton fabric.

The total work of rupture (toughness) has been calculated by the following equation;

Since Work done = force ×displacement = *F*.d*l*

Then Total work done in breaking the fiber = work of rupture $\int_0^{break} F.dl$ [7]

The toughness of PET/flax fabrics was calculated by substituting in the following equations and numerical values listed in table (3) which are extracted from Figure (2) which represent the initial and final values at break for both tensile strength and elongation.

Table (3) Numerical values for calculating toughness of PET/flax fabric

x	0	2
y	200	612

$$\text{slope} = \frac{y2 - y1}{x2 - x1}$$

$$slope = \frac{612 - 200}{2 - 0} = 206$$

$$f(x) = 206x + 200$$

$$\int_0^2 206x + 200 = 812 \qquad Equation(1)$$

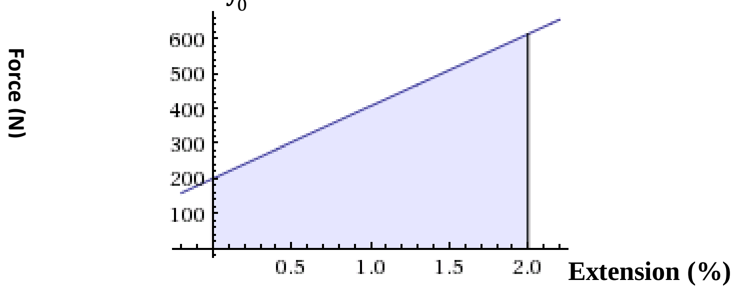


Fig (2) Toughness of PET/flax fabric

The toughness of PET/cotton fabrics was calculated by substituting in the following equations and numerical values listed in table (4) which are extracted from Figure (3) which represent the initial and final values at break for both tensile strength and elongation.

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Table (4) Numerical values for calculating toughness of PET/cotton fabric

x	0	5.25
y	30	460

$$\text{slope} = \frac{y2 - y1}{x2 - x1}$$

$$slope = \frac{460 - 30}{5.25 - 0} = 81.9$$

$$f(x) = 81.9\,x + 30$$

$$\int_0^{5.25} 81.9\,x + 30 = 1286.1 \qquad Equation(2)$$

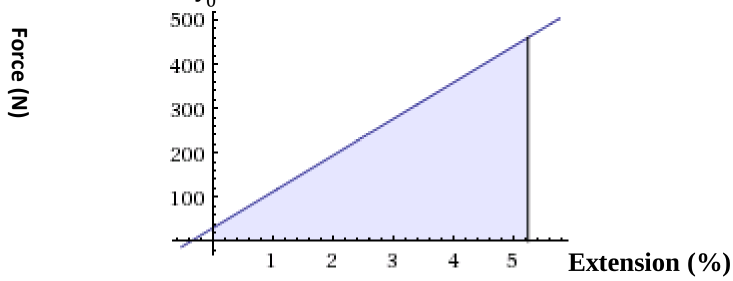

Fig (3) Toughness of PET/cotton fabrics

The toughness of PET/rayon fabrics was calculated by substituting in the following equations and numerical values listed in table (5) which are extracted from Figure (4) which represent the initial and final values at break for both tensile strength and elongation.

Table (5) numerical values for calculating toughness of PET/rayon fabric

x	0	15
y	60	580

$$\text{slope} = \frac{y2 - y1}{x2 - x1}$$

$$slope = \frac{580 - 60}{15 - 0} = 34.66$$

$$f(x) = 34.66\,x + 60$$

$$\int_0^{15} 34.66\,x + 60 = 4800 \qquad Equation\ (3)$$

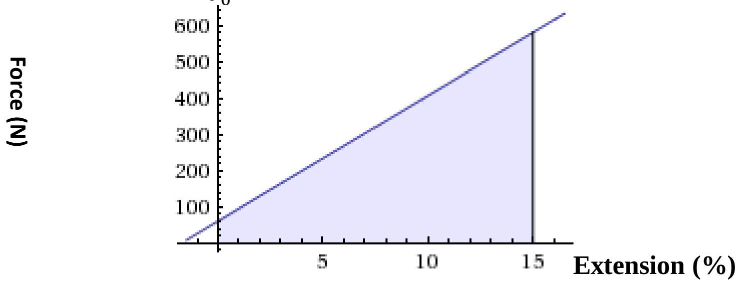

Fig. (4) Toughness of PET/rayon fabrics

Finally, this leads to the conclusion that the durability of PET/rayon is more than PET/cotton but the PET/flax has the least durability.

V. CONCLUSION

In this study three plain 1/1 samples were weaved where all the warp yarns were made of 100% PET fibers, whereas flax, cotton, and rayon were used as weft yarns respectively for each sample in combination to the aforementioned 100% PET warp yarns.
The results can be summarized as follows:

1. When a material is strong, it isn't necessarily going to be tough.
2. Flax fibers in PET/flax fabric show the highest tensile strength when compared to rayon viscose , and cotton respectively, but the elongation of flax is the least. So the flax fiber is classified as brittle.

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3. Contrary to the well known scientific fact that there is a positive relation between crystalline region of fibers and the tensile strength which dictates that cotton fibers posses higher tensile strength than rayon fibers, the rayon fibers in PET/rayon fabric scored higher tensile strength results than cotton fibers in PET/cotton fabric. This odd observation can be explained by the fiber length of the rayon which was found to be around 80 mm while the length of cotton was around 36 mm.
4. Toughness of PET/rayon fabric is more than PET/cotton fabric, on the other hand the PET/flax fabric proved to be brittle.

VI. REFERENCES

1. Ž. Zupin and K. Dimitrovski, "Mechanical properties of fabrics from cotton and biodegradable yarns bamboo, SPF, PLA in weft," *V Woven Fabr. Eng. Uredila Pol. Dobnik-Dubrovski Rij. Sciyo Cop*, p. 25, 2010
2. S. Guowen, *Improving comfort in clothing*. Woodhead Publishing Limited, 2011
3. E. P. G. Gohl and L. D. Vilensky, *Textile Science: An Explanation of Fibre Properties*. Melbourne Victoria: Longman, 1981.
4. G. Odian, *Principles of Polymerization*, 4 edition. Hoboken, N.J: Wiley-Interscience, 2004.
5. J. Hu, *Structure and mechanics of woven fabrics*, 1 edition. Boca Raton, Fla. : Cambridge: CRC Press, 2004.
6. B. P. Saville, *Physical Testing of Textiles*, 1 edition. Cambridge, England : Boca Raton, Fla: CRC Press, 1999.
7. J. W. S. Hearle and W. E. Morton, *Physical Properties of Textile Fibres, Fourth Edition*, 4th edition. Cambridge: Woodhead Publishing, 2008.
8. J. W. S. Hearle, P. Grosberg, and S. Backer, *Structural Mechanics of Fibers, Yarns, and Fabrics Volume 1*. New York: John Wiley & Sons Inc, 1969.
9. F. Hosseinali, "Investigation on the Tensile Properties of Individual Cotton (Gossypium hirsutum L.) Fibers," Texas Tech University, 2012.
10. "ASTM D5035 - 11: Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)." 2011.
11. S. Grundas, Ed., *Advances in Agrophysical Research*. InTech, 2013.

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(Annex. A-1)

Tensile strength in warp direction(N)

	R1	R2	R3
PET/ flax	1758	1812	1982
PET/ cotton	2065	2125	2163
PET/ viscose	1718	1992	2128

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
PET/ flax	3	5552	1850.667	13665.33
PET/ cotton	3	6353	2117.667	2441.333
PET/ viscose	3	5838	1946	43612

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	109846.9	2	54923.44	2.759109	0.141351	5.143253
Within Groups	119437.3	6	19906.22			
Total	229284.2	8				

Elongation in warp direction (%)

	R1	R2	R3
PET/ flax	40.1	63.6	78.5
PET/ cotton	60.6	72	55.9
PET/ viscose	61.3	64.5	68.9

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
PET/ flax	3	182.2	60.73333	374.8033
PET/ cotton	3	188.5	62.83333	68.54333
PET/ viscose	3	194.7	64.9	14.56

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	26.04222	2	13.02111	0.085309	0.919323	5.143253
Within Groups	915.8133	6	152.6356			
Total	941.8556	8				

(Annex. A-2)

Tensile strength in weft direction(N)

	R1	R2	R3
PET/ flax	674	610	552
PET/ cotton	439	444	496.8
PET/ viscose	579	584	577

SUMMARY

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Groups	Count	Sum	Average	Variance
PET/ flax	3	1836	612	3724
PET/ cotton	3	1379.8	459.9333	1025.613
PET/ viscose	3	1740	580	13

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38564.28	2	19282.14	12.14594	0.007771	5.143253
Within Groups	9525.227	6	1587.538			
Total	48089.5	8				

Elongation in weft direction (%)

	R1	R2	R3
PET/ flax	1.787	2.2	1.9
PET/ cotton	4.85	5.6	5.3
PET/ viscose	15.39	14.6	15.1

SUMMARY

Groups	Count	Sum	Average	Variance
PET/ flax	3	5.887	1.962333	0.045556
PET/ cotton	3	15.75	5.25	0.1425
PET/ viscose	3	45.09	15.03	0.1597

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	277.2211	2	138.6105	1195.756	1.57E-08	5.143253
Within Groups	0.695513	6	0.115919			
Total	277.9166	8				